

[54] ABSORPTION REFRIGERATION SYSTEM WITH MULTIPLE ABSORPTION

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Related U.S. Application Data

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[51] Int. Cl.F25b 15/04

[58] Field of Search62/476, 485, 489, 495

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Primary Examiner—William F. O'Dea

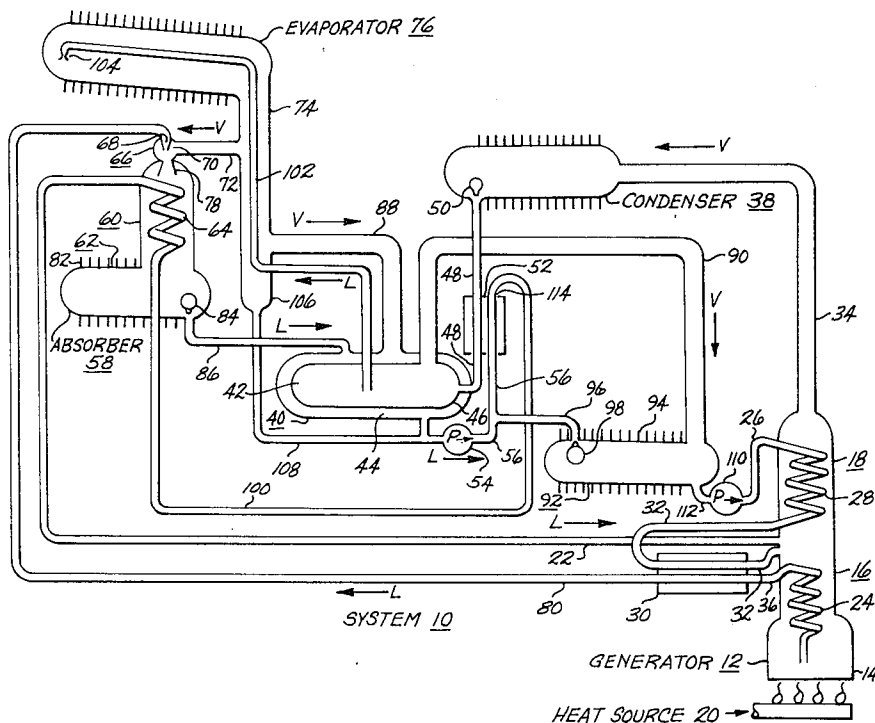
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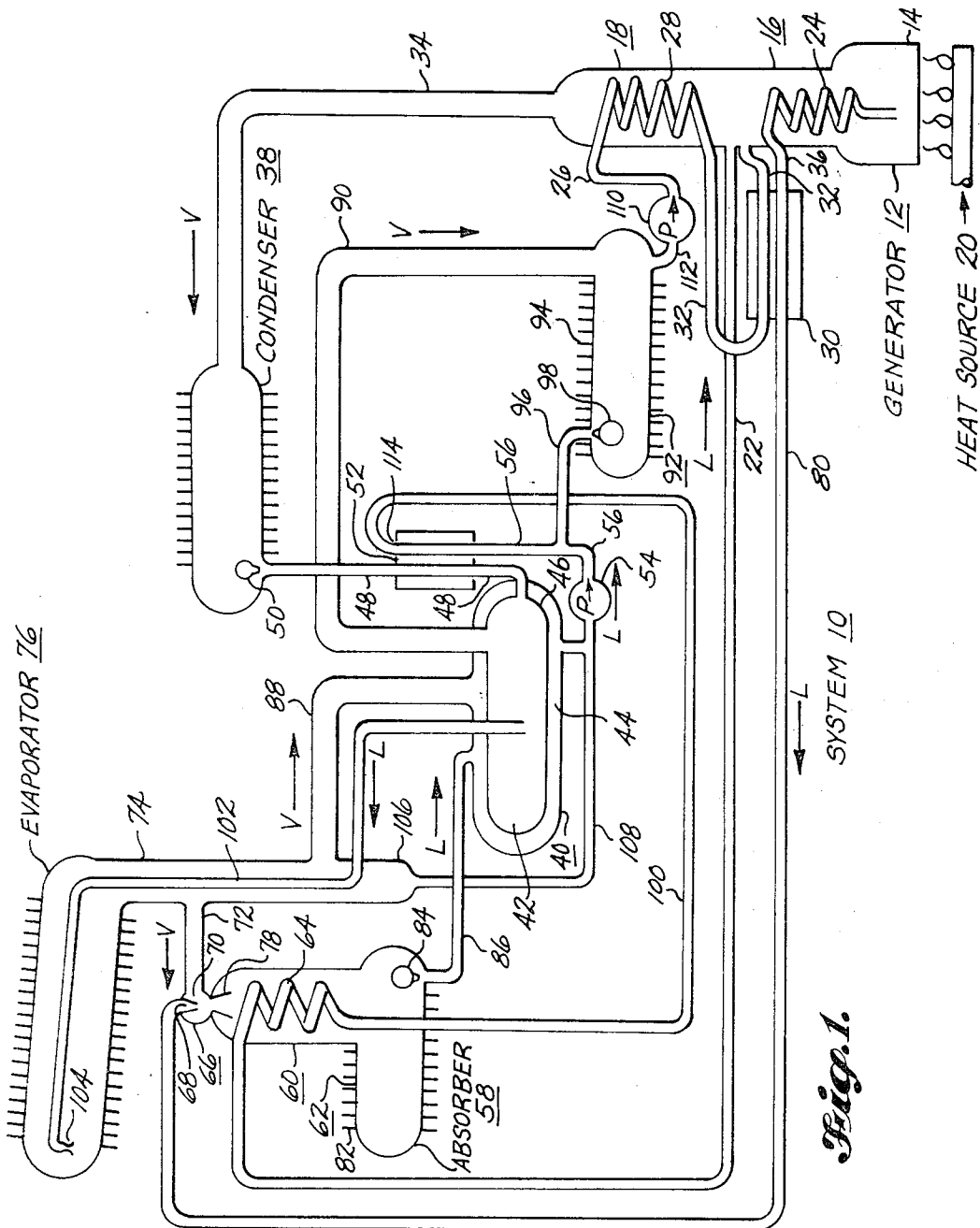
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[57] ABSTRACT

This refrigeration system includes a first absorber, an evaporation heat exchanger, and a second absorber for drawing refrigerant vapor from the evaporation heat exchanger, which components are so interconnected with one another and with a plurality of heat exchangers and an inductor as to permit the system's condenser to operate at a temperature higher than that in the first and in the second absorber, which are ambient cooled, so that a single source of cooling air of minimum quantity can flow first over such absorbers and then over the condenser while still maintaining a good C.O.P. for the refrigeration system.

11 Claims, 4 Drawing Figures





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Fig. 2a.

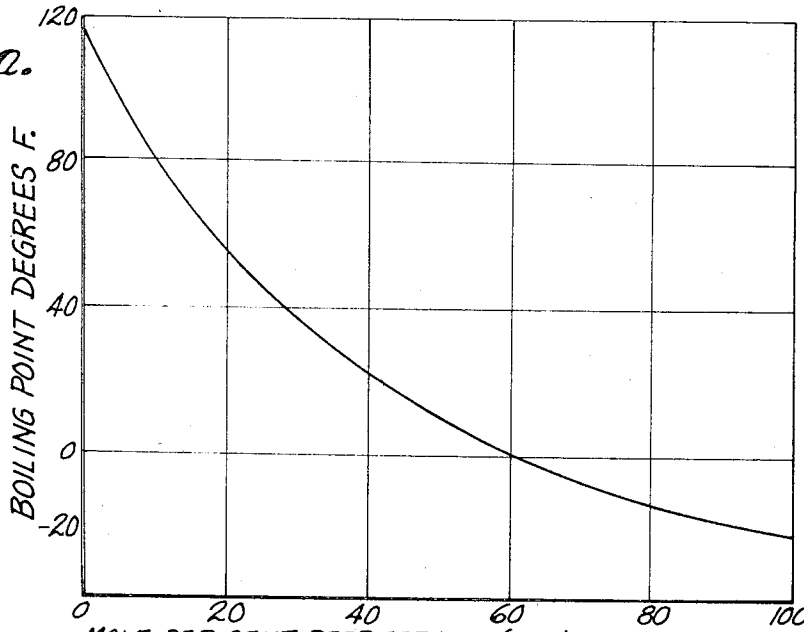


Fig. 2b.

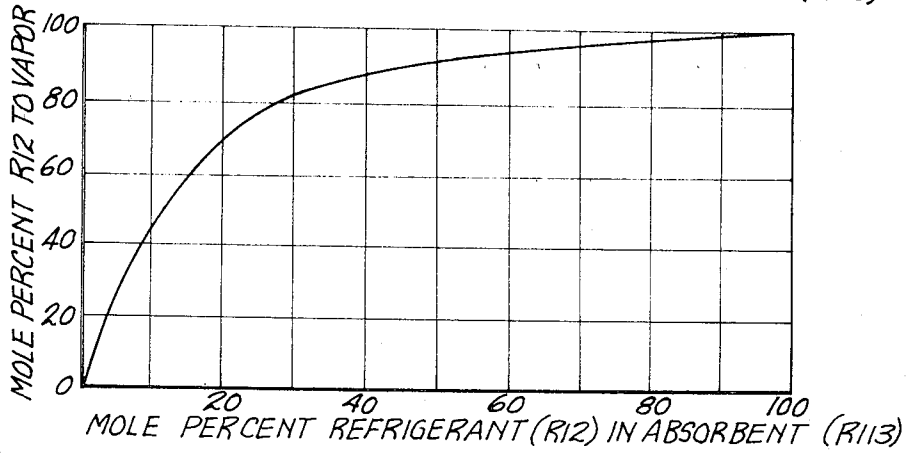
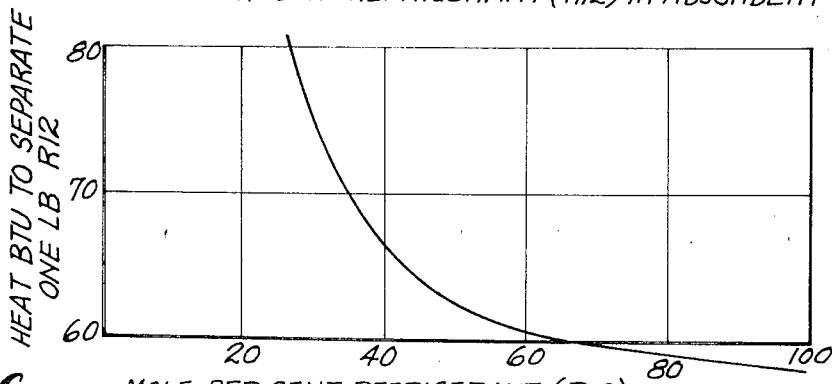


Fig. 2c.

MOLE PER CENT REFRIGERANT (R12)
IN ABSORBENT (R113)

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ABSORPTION REFRIGERATION SYSTEM WITH MULTIPLE ABSORPTION

This application is a continuation-in-part application of U.S. Pat. application Ser. No. 791,650 filed Jan. 16, 1969 and now U.S. Pat. No. 3,552,142 by the same applicant and entitled "Absorption Refrigeration System With Multiple Absorption Stages."

This invention relates to thermally powered absorption-type refrigeration systems, and more particularly to such a refrigeration system capable of employing nonflammable and safe fluorocarbon refrigerants with a desirably high coefficient of performance for the system.

In the refrigeration system shown and described in the aforementioned patent application Ser. No. 791,650 substantially all of the heat of the system that must be dissipated is dissipated from the system's condenser or at a temperature corresponding to the operating temperature of the condenser. This means that the condenser can be remotely located from the rest of the system, however, the condenser must be relatively large and a relatively large quantity of cooling air must be circulated over the condenser in order to effectively dissipate the heat from the condenser.

A feature of the invention of the present application is that the system's condenser is not remotely located from the ambient cooled absorbers of the refrigeration system and a single source of cooling air of relatively smaller quantity is circulated first over the ambient cooled absorbers and then over the condenser which is at a higher operating temperature than the ambient cooled absorbers. Thus, the same airstream is able to cool both the ambient cooled absorbers and the condenser, since even though the airstream is warmed in passing over the absorbers, it still can effectively dissipate the heat from the condenser, since the condenser is operating at a higher temperature than the ambient cooled absorbers. In contrast, in the refrigeration system shown and described in patent application Ser. No. 791,650 the evaporation heat exchanger is the only absorption functioning component operating at a temperature less than that of the associated condenser. Such being the case, one could not effectively dissipate the heat from the condenser by flowing the airstream first over the absorbers and then over the condenser.

Although it is desirable to have a single source of cooling air of relatively small quantity for dissipating the heat from both the ambient cooled absorbers and the condenser, this presents a problem. With the condenser operating at a higher temperature it also operates at a correspondingly higher pressure which correspondingly increases the back pressure on the generator thus raising the boiling point of the operating liquids in the generator. This means that unless something is done, more heat will have to be applied to the generator to get the same cooling effect. It has been discovered that this undesirable effect of increased back pressure in the generator can be offset while still maintaining a good coefficient of performance for the refrigeration system by changing the system shown and described in patent application Ser. No. 791,650 in several respects. First, heat can be sent back into the generator by providing a generator fluid heat exchanger for the refrigeration system and by so interconnecting it in the system that the solution of refrigerant and absorbent material leaving the output of the rectifier section of the generator is, before it reenters the generator, heat exchanged with the hot absorbent material leaving the generator. Secondly, this heat transfer is made more effective by dividing the solution of refrigerant and absorbent material coming from the evaporation heat exchanger and sending only a portion of such solution to the final high-pressure absorber so that in that portion the saturation concentration of refrigerant in the solution of refrigerant and absorbent material is increased, thus lowering the boiling point of the solution of refrigerant and absorbent material so that the heat received in the rectifier section plus that received in the generator fluid heat exchanger is more adequate for preheating the solution flowing from the heat exchange tube of the rectifier section and within the generator fluid heat exchanger toward or to its boiling point before such

preheated solution enters the space of the generator. Thirdly, by providing a heat exchanger for precooling the condensed refrigerant coming from the condenser before it enters the evaporator section of the evaporation heat exchanger the saturation concentration of refrigerant in the solution of refrigerant and absorbent material in the evaporation heat exchanger is increased, since heat from the condenser is prevented from being convected to the evaporation heat exchanger. Fourthly, by providing an inductor in the refrigeration system the pressure within the first stage absorber is increased to a pressure above that in the main evaporator, which in turn raises the temperature at which absorption takes place within the first stage absorber. This raises the temperature of the solution of refrigerant and absorbent material within the preheat exchanger of the first stage absorber to thus carry more heat back to the generator. In addition, by increasing the vapor pressure of refrigerant within the first stage absorber to a pressure above that in the main evaporator, the main evaporator is permitted to operate at a lower temperature with respect to the condenser and the generator.

Therefore, an object of this invention is to provide a practical air-cooled absorption-type refrigeration and air-conditioning system that can use safe and nonflammable fluorocarbon compounds for the refrigerant and the absorbent material.

Another object of this invention is to provide an absorption-type refrigeration and air-conditioning system that will permit the same cooling air to first be used to cool the ambient cooled absorbers and then cool the condenser which is operating at a higher temperature than the ambient cooled absorbers while at the same time maintaining a good coefficient of performance for the refrigeration and air-conditioning system.

A further object of this invention is to increase the saturation concentration of the refrigerant in the solution of refrigerant and absorbent material in the absorbers of the refrigeration system so that preheating of a portion of such resulting solution toward or to its boiling point can be accomplished with recovered heat before such portion of solution enters the generator space, even with the condenser operating at a temperature above that of the absorbers that are ambient cooled.

A still further object of this invention is to permit the condenser of an absorption-type refrigeration system to operate at a temperature above that of the first stage ambient cooled absorber receiving refrigerant vapor from the evaporator, while at the same time maintaining the temperature of the evaporation heat exchanger, which is evaporatively cooled, below the temperature of the first stage ambient cooled absorber.

Still another object of this invention is to permit, in an absorption-type refrigeration system, a greater practical operating temperature difference between the condenser and the main evaporator.

Other objects of this invention will become apparent from the following description when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic diagram of a preferred embodiment of this invention in which means is provided for accomplishing the foregoing objects in a thermally powered absorption-type refrigeration system utilizing relatively nonpolar working substances.

FIG. 2a through 2c are graphs illustrating in the case of a suitable solution of dichlorodifluoromethane (R12) as refrigerant in trichlorotrifluoroethane (R113) as absorbent, what effect molar percent concentration of a refrigerant has on the three important solution properties, namely, boiling point, approximate molar percent composition of vapor boiling from the liquid solution, and the calculated amount of heat required to boil off each pound of refrigerant. The general trends of these curves are representative of those properties of refrigerant and absorbent material that are characteristic of nonpolar compounds which have weak chemical affinity for each other.

Referring to FIG. 1 there is shown a thermally powered absorption-type refrigeration system 10 illustrating the preferred embodiment of this invention in which relatively nonpolar working substances such as dichlorodifluoromethane (R12) and trichlorotrifluoromethane (R113) are utilized. Of course, it is to be understood that other suitable nonpolar working substances could be utilized.

A generator 12 has as functional sections a boiler section 14, an analyzer section 16 and a rectifier section 18, and is heated by a heat source 20. Preheated rich solution of refrigerant and absorbent material that has been increased in concentration of refrigerant enters the analyzer section 16 and flows over a heat exchange tube 24 which conveys an absorbent solution strong in absorbent material from the bottom portion of the boiler 14, to thereby produce refrigerant-rich vapor. A rich solution of refrigerant and absorbent material cooler than that entering by way of the conduit 22 enters the rectifier section 18 of the generator 12 by way of the conduit 26 and flows through a heat exchange tube 28 of the receiver section 18.

In order to send heat back into the generator 12 a generator fluid heat exchanger 30 is provided. Delivery means, specifically conduit means 32, is provided for delivering the rich solution of refrigerant and absorbent material from the heat exchange tube 28, of the rectifier section 18, through the generator fluid heat exchanger 30 and into the analyzer section 16, of the generator 12, to thus also produce refrigerant-rich vapor as the solution of refrigerant and absorbent material flows down over the surface of the hot heat exchange tube 24. As the thus produced refrigerant-rich vapor flows upward through the rectifier section 18 in contact with the cooler heat exchange tube 28, absorbent material is condensed from the vapor, thus leaving nearly pure refrigerant vapor to be discharged by way of a conduit 34. Delivery means, specifically a conduit 36, is provided for delivering a hot solution of refrigerant and absorbent material which is strong in absorbent material from the heat exchange tube 24, of the analyzer section 16 to the generator fluid heat exchanger 30, to thus heat exchange the hot solution of refrigerant and absorbent material leaving the generator 12 with the rich and relatively cooler solution of refrigerant and absorbent material that flows from the heat exchange tube 28 of the rectifier section 18, through the conduit means 32, the generator fluid heat exchanger 30, and the conduit means 32 and into the analyzer section 16, to thereby return heat back to the generator 12.

A condenser 38 which is cooled by ambient air through cooling fins in the conventional manner, receives and condenses refrigerant vapor. The vapor pressure within the condenser 38 is at substantially the same value as the vapor pressure within the generator 12. An evaporation heat exchanger 40 that has two compartments, an inner compartment 42 and an outer compartment 44, separated by an extensive heat exchange partition 46, receives from the condenser 38 condensed refrigerant into the inner compartment 42 by means of conduit means 48 and a flow regulator 50. In order to precool the condensed refrigerant flowing from the condenser 38 and into the inner compartment 42 of the evaporation heat exchanger 40, a liquid-to-liquid heat exchanger 52 is provided. Specifically, the solution of refrigerant and absorbent material that is pumped by a pump 54 from the outer compartment 44 through conduit means 56 and into the heat exchanger 52 is heat exchanged with the relatively warmer condensed refrigerant flowing through the conduit means 48 to provide, as will be explained more fully hereinafter, a greater saturation concentration of refrigerant in solution of refrigerant and absorbent material within the outer compartment 44. Thus, the amount of heat being convected from the condenser 38 to the evaporation heat exchanger 40 is minimized.

An absorber 58 has two main sections, a high-temperature section 60 and an ambient temperature section 62. The high-temperature section 60, of the absorber 58, houses a preheat exchanger 64 which is shown as a tube formed into a helical

coil through which a solution of refrigerant and absorbent material rich in refrigerant flows so as to be preheated from other liquid on the outer surface of the preheat exchanger 64.

In order to increase the pressure within the absorber 58 to a pressure greater than that within the evaporator 76 an inductor 66 is provided. The inductor 66 includes a primary nozzle 68, a secondary inlet 70 which is connected by conduits 72 and 74 to an evaporator 76 to receive refrigerant vapor from the evaporator 76, and a discharge 78 for discharging refrigerant vapor and a hot solution of refrigerant and absorbent material strong in absorbent material into the high-temperature section 60. By increasing the pressure within the high-temperature section 60 the temperature at which absorption takes place within the section 60 is increased. This raises the temperature of the solution of refrigerant and absorbent material within the preheat exchanger 64 to thus effect a carrying of more heat back to the generator 12 through the conduit 22. In addition, by increasing the vapor pressure of refrigerant within the absorber 58 more refrigerant vapor is absorbed and the evaporator 76 is permitted to operate at a lower temperature with respect to the condenser 38 and the generator 12. A conduit 80 is interconnected between the generator fluid heat exchanger 30 and the primary nozzle 68 of the inductor 66 for delivering hot solution of refrigerant and absorbent material strong in absorbent material to the absorber 58. The strong absorbent solution discharged from the discharge 78, of the inductor 66, spreads out over the surface of the preheat exchanger 64 in absorbing contact with refrigerant vapor received from the main evaporator 76, which evaporator 76 provides a cooling effect to the space to be cooled or refrigerated. The refrigerant vapor from the evaporator 76 enters the high-temperature section 60, of the absorber 58, by means of conduits 74 and 72 and the secondary inlet 70 and discharge 78 of the inductor 66 at a pressure higher than that within the evaporator 76 and heats the preheat exchanger 64 and the rich solution of refrigerant and absorbent material therein with which it is in thermal contact as refrigerant vapor is absorbed within the high-temperature section 60 and liberates its heat of vaporization. As the liquid absorbent material within the high-temperature section 60 becomes laden with refrigerant, the resulting rich solution of refrigerant and absorbent material drops into the ambient temperature section 62 of the absorber 58, where more refrigerant vapor can be absorbed at near ambient temperature. The heat that is generated by this latter absorption is dissipated by cooling air flowing over the fins 82 of the ambient temperature section 62.

The evaporation heat exchanger 40 includes the outer compartment 44 which is insulated from ambient heat, and the inner compartment 42 which functions as an evaporator. The evaporation heat exchanger 40 is operatively associated with the absorber 58 and with the condenser 38 so that a solution of refrigerant and absorbent material passes from the absorber 58 through a flow regulator 84 and a conduit 86 and into the outer compartment 44, of the evaporation heat exchanger 40, and so that condensed refrigerant passes from the condenser 38 through the flow regulator 50 and the conduit means 48 and into the inner compartment 42 of the evaporation heat exchanger 40. The evaporation heat exchanger 40 is also operatively associated with the evaporator 76 so that a portion of the refrigerant evaporated within the evaporator 76 passes through the conduit 74 and a conduit 88 into the outer compartment 44 of the evaporation heat exchanger 40 and is absorbed by the cooled absorbent material within the outer compartment 44. Absorbent liquid material and its dissolved refrigerant drains from the absorber 58 to the outer compartment 44 of the evaporation heat exchanger 40 by the conduit 86 and is disposed in heat transfer relationship with the inner compartment 42 of the evaporation heat exchanger 40. Condensed refrigerant enters the inner compartment 42, in which the vapor pressure is above the pressure within the evaporator 76, by means of the conduit means 48 and the heat exchanger 52. Refrigerant vapor is withdrawn from the inner compart-

ment 42 through a conduit 90 into an ambient cooled absorber 92, having heat dissipating means such as fins 94, and cooling within the inner compartment 42 results from evaporation of a portion of the liquid refrigerant disposed within the inner compartment 42; and absorbent material with dissolved refrigerant disposed within the outer compartment 44 is likewise cooled below ambient temperature as it flows from the conduit 86 and spreads over the partition 46 of the inner compartment 42, of the evaporation heat exchanger 40, in absorbing contact with refrigerant vapor received from the conduits 74 and 88. The absorbent material thus cooled acquires the capacity to absorb considerably more refrigerant vapor, therefore more refrigerant vapor is absorbed by the solution to thus become a richer solution of refrigerant and absorbent material, and heat thus liberated is removed by evaporation of refrigerant liquid within the inner compartment 42; in other words the saturation concentration of the refrigerant in the solution of refrigerant and absorbent material within the outer compartment 44 is increased.

In order to deliver a portion of the solution of refrigerant and absorbent material of increased refrigerant concentration from the outer compartment 44 of the evaporation heat exchanger 40 and into the absorber 92 at a pressure that is higher than the pressure within the outer compartment 44 of the evaporation heat exchanger 40, the conduit means 56, a conduit 96, a flow regulator 98 and the pump 54 are provided. On the other hand, in order to deliver another portion of the solution of increased refrigerant concentration from the outer compartment 44 through the heat exchanger 52 and to the preheat exchanger 64 of the absorber 58, the pump 54, the conduit means 56 and a conduit 100 are provided. By sending only a portion of the solution within the outer compartment 44, of the evaporation heat exchanger 40 to the absorber 92, the saturation concentration of refrigerant in the solution of refrigerant and absorbent material within the absorber 92 is increased, since there is less solution in the absorber 92 for the vapor received from the conduit 90 to combine with. Thus, the heat received in the rectifier section 18 plus that received in the generator fluid heat exchanger 30 is sufficient to preheat the rich solution flowing from the heat exchange tube 28 and within the generator fluid heat exchanger 30 toward or to its boiling point before the rich solution of refrigerant and absorbent material enters the space of the generator 12.

The remaining cooled liquid refrigerant disposed within the inner compartment 42, of the evaporation heat exchanger 40, is conveyed to the evaporator 76 by means of a siphon tube 102 which has a flow control 104 for regulating the flow of liquid refrigerant to the evaporator 76. The inner compartment 42 of the evaporation heat exchanger 40 thus functions also as a refrigerant precooler for the refrigerant liquid conveyed to the evaporator 76.

The evaporator 76 as illustrated is of the conventional finned type which evaporates at reduced pressure refrigerant liquid which is received through the siphon tube 102 to thereby cool the surrounding space. Resulting cool refrigerant vapor leaves the evaporator 76 through the conduit 74 in heat transfer relationship with the liquid within the siphon tube 102 and the refrigerant liquid therein is further cooled before entering the evaporator 76.

A sump 106 is provided to collect any overflow nonevaporated liquid refrigerant from the evaporator 76 and return it to the generator 12. For such purpose a conduit 108 is interconnected between the sump 106 and the pump 54.

In order to deliver the solution of refrigerant and absorbent material that is further increased in concentration of refrigerant from the absorber 92 to the heat exchange tube 28 of the rectifier section 18, a pump 110 and associated conduits 26 and 112 are provided.

The operation of the absorption type refrigeration system 10 as shown in FIG. 1 will now be described with a suitable refrigerant dichlorodifluoromethane (R12) and a suitable absorbent material trichlorotrifluoroethane (R113), the latter of which has a much higher boiling point than the refrigerant in absorbent as illustrated by FIG. 2a.

Liquid solution of absorbent material containing a relatively high concentration of dissolved refrigerant, in other words a rich solution, is pumped into the heated generator 12 by way of the conduit 22 and by way of the conduit 26, the heat exchange tube 28, the conduit means 32, the generator fluid heat exchanger 30 and the conduit means 32. Such rich solution that enters the generator 12 runs down over the surface of the heat exchange tube 24 in the presence of hot vapor rising from the boiler 14 so that vapor is distilled off with changing composition according to FIG. 2b so that at all positions downward through the analyzer 16 the vapor produced is richer in refrigerant than the liquid from which it is distilled, but both liquid and vapor are progressively less rich in refrigerant toward the bottom of the boiler 14 where the temperature must also be higher according to FIG. 2a. Rising vapor is then stripped of absorbent vapor by condensing the absorbent vapor as the mixed vapor passes upward over the cooler surface of the heat exchange tube 28 so that rectified refrigerant vapor is discharged to the condenser 38 at essentially condenser pressure by way of the conduit 34. At the same time, strong hot absorbent material that reaches the bottom of the boiler section 14 of the generator 12 leaves through the heat exchange tube 24, where sensible heat from the hot absorption material is transferred to the incoming rich solution, and the strong absorbent material returns to the absorber 58 through the conduit 36, the heat exchanger 30, the conduit 80, and the primary nozzle 68 and the discharge 78 of the inductor 66. The rich solution of refrigerant and absorbent material flowing from the heat exchange tube and through the generator fluid heat exchanger 30 is heat exchanged with the strong hot absorbent material flowing through the generator fluid heat exchanger 30 so as to return heat to the generator through the conduit means 32.

The amount of heat in B.t.u. required to separate each pound of refrigerant vapor that is returned to the condenser 38 is determined by the concentration of refrigerant in terms of mole percent of refrigerant in the vapor derived from the rich solution entering the analyzer section 16 of the generator 12 as shown by the graph of FIG. 2c. The reason for the lower value of heat required for evaporating each pound of refrigerant from the solution of refrigerant in absorbent material in the solution as measured in mole percent becomes richer according to FIG. 2c, is that the molar heat of vaporization for the absorbent material is much greater than that of the refrigerant, and that according to FIG. 2b molar amount of absorbent material originally evaporated with each mole of refrigerant vapor is much less with the use of richer solution of refrigerant in absorbent material. Furthermore, preheating of the rich solution before it enters the generator reduces the amount of heat that must be applied to the generator 12 by the heat source 20. It follows that the rich solution entering the analyzer section 16 should have a high concentration of refrigerant.

The separated strong liquid absorbent material is allowed to return to the high-temperature section 60, of the absorber 58, by way of the conduit 80 at a temperature comparable to that within the high-temperature section 60. The strong absorbent solution follows from the conduit 80 through the primary nozzle 68 and the discharge 78, of the inductor 66, to thereby draw refrigerant vapor from the evaporator 76 through the conduits 74 and 72 and thus discharge the refrigerant vapor and the strong absorbent solution into the high-temperature section 60 at a pressure above that in the evaporator 76, to thereby increase the pressure within the absorber 58, to thus send more heat back to the generator 12 through the conduit 22, as hereinbefore explained, and to permit the evaporator 76 to operate at a lower temperature with respect to the condenser 38 and the generator 12. The strong absorbent solution spreads down over the preheat exchanger 64 where refrigerant vapor which is supplied by the evaporator 76 is absorbed. The absorption of the refrigerant in the strong absorbent solution liberates heat of condensation at a sufficiently high temperature to heat the rich solution within the preheat exchanger 64 of the absorber 58. Fresh refrigerant liquid is

supplied to the evaporator 76 from the evaporation heat exchanger 40 through the siphon tube 102. The resulting heat of condensation plus the original sensible heat of the entering strong absorbent solution is transferred through the walls of the preheat exchanger 64 to the rich solution of refrigerant that is within the preheat exchanger 64 to preheat the rich solution of refrigerant in absorbent that is to be returned to the generator 12. Additional refrigerant vapor from the evaporator 76 is absorbed in the solution in the ambient temperature section 62 of the absorber 40, and the liberated heat is dissipated by air circulating over the fins 82.

The resulting solution of refrigerant in absorbent material is delivered by means of the conduit 86 into the outer compartment 44, of the evaporation heat exchanger 40, where it is cooled by thermal contact with the inner compartment 42, where a portion of the refrigerant received from the condenser 38 is evaporated at a temperature and corresponding pressure intermediate between the evaporator 76 and the condenser 38 to thus produce the cooling effect required in the outer compartment 44 of the evaporation heat exchanger 40. The cooling of the solution of refrigerant in absorbent material within the outer compartment 44 of the evaporation heat exchanger 40 reduces its vapor pressure to a value sufficiently less than the vapor pressure within the evaporator 76 that additional vapor is caused to flow from the evaporator 76 through the conduits 74 and 88 and into the outer compartment 44 where it is absorbed in the solution of refrigerant in absorption material received from the absorber 58 through the conduit 86, thus enriching the solution. Cooling effect caused by evaporation of a portion of the refrigerant within the inner compartment 42 of the evaporation heat exchanger 40 also precools the remaining portion of the refrigerant liquid which leaves by means of the siphon tube 102 and the flow control 104 to the evaporator 76.

The solution of refrigerant and absorbent material of increased refrigerant concentration then joints any overflow refrigerant from sump 106 through the conduit 108 and a portion of the combined solution is delivered by the pump 54 and associated conduits 56 and 96 to the absorber 92 through the flow regulator 98 where further refrigerant vapor evaporated from within the inner compartment 42 of the evaporation heat exchanger 40 is absorbed at a temperature slightly above ambient, which is due to the vapor pressure being greater than the vapor pressure within the evaporator 76 as communicated to the outer compartment 44, to thereby further increase the saturation concentration of refrigerant in the solution of refrigerant and absorbent material within this absorber 92; in other words, the solution becomes rich with a consequent lowered boiling point. Heat produced within the absorber 92 is dissipated by cooling air flowing over the fins 94, of the absorber 92.

The rich refrigerant solution within the absorber 92 is then delivered by the pump 110 and associated conduits 112 and 26 to the heat exchanger tube 28 of the rectifier 18. The remaining portion of the combined solution received from the conduit 108 and the outer compartment 44, of the evaporation heat exchanger 40, is pumped by the pump 54 through the conduit means 56, the heat exchanger 52, and the conduit 100 to the preheat exchanger 64 of the absorber 58. The solution of refrigerant and absorbent material that enters the preheat exchanger 64 flows therethrough and through to conduit 22, to thus return heat to the generator 12.

The refrigerant condensed in the condenser 38 flows from the condenser 38 through the flow regulator 50, the conduit means 48, the heat exchanger 52, and the conduit means 48, and into the inner compartment 42 of the evaporation heat exchanger 40, to provide necessary cooling to maintain the temperature below ambient in the inner compartment 42. The condensed refrigerant flowing from the condenser 38 and into the inner compartment 42 is precooled before entering the inner compartment 42 by heat exchanging this condensed refrigerant in the heat exchanger 52 with the cooler solution of refrigerant and absorbent material within the heat

exchanger 52 that is flowing to the preheat exchanger 64 of the absorber 58.

In operation, a fan (not shown) is used to blow air first over the ambient temperature section 62 of the absorber 58, and the absorber 92, and then over the condenser 38 which is operating at a higher temperature than the ambient temperature section 62 and the absorber 92. Thus, the cooling air is warmed up as it flows over the section 62 and the absorber 92 and yet is not so warm but that it still can effectively dissipate the heat from the condenser 38.

It is to be understood that the inductor 66 may be omitted, in which case the conduit 72 would communicate directly with the absorber 58 and the conduit 80 would communicate directly with the upper portion of the high-temperature section 60 of the absorber 58. If the inductor 66 were removed the vapor pressure within the absorber 58 would not be greater than the vapor pressure within the evaporator 76.

It is also to be understood that the conduit 96 could connect to the conduit 100 instead of to the conduit means 56 as shown. In such case all of the solution of refrigerant and absorbent material pumped by the pump 54 would flow through the heat exchanger 52. Another alternative would be to connect the end of the conduit 100 to the conduit means 56 at the output of the pump 54 and to connect conduit 96 to the output of the heat exchanger 52 at the point 114.

It is to be understood that the evaporator 76 can be divided into two sections (not shown) which are supplied with refrigerant liquid by separate conduits (not shown) connected to receive condensed refrigerant from the condenser 38. One such section of the evaporator delivers vapor refrigerant through a separate conduit (not shown) to only the outer compartment 44 of the evaporation heat exchanger 40, and the other such section of the evaporator delivers vapor refrigerant through another separate conduit (not shown) to only the secondary inlet 70 of the inductor 66, thus replacing the conduits 72, 74 and 88, so that the two sections of the evaporator can operate at separate temperatures and pressure such that the vapor pressure inside the absorber 58 may be at a still higher pressure than the vapor pressure inside the outer compartment 44 of the evaporation heat exchanger 40. Of course separate sumps (not shown) such as the sump 106 must be provided for such sections of the evaporator and separate conduits (not shown) such as the conduit 108 must be provided for returning overflow and unevaporated refrigerant from each such section of the evaporator to the pump 54. By providing such separate sections (not shown) for the evaporator and by connecting them to the remainder of the apparatus as heretofore described, the coefficient of performance of the system is improved, particularly when the cooling load is high and the air temperature has thereby risen in the space to be cooled by these two sections of the evaporator. This improvement in coefficient of performance at the time when most desired is effected by the arrangement such that the higher temperature and pressure section of the evaporator is staged in the space airstream so that the warmer air contacts it first before it does the lower pressure section of the evaporator, thus permitting the high-temperature and pressure section of the evaporator to absorb much more heat and produce correspondingly more refrigerant vapor which, with its higher pressure, is absorbed in the first absorber 58 to increase the amount of useful heat liberated in the high temperature section 60 of the absorber 58 and that is transferred to the rich solution within the preheat exchanger 64, to thereby increase the amount of heat carried back to the generator 12 by the rich solution. Of course, the concentration of refrigerant in the rich solution leaving the absorber 58 by the conduit 86 is also increased, which reduces the amount of absorption required in the evaporation heat exchanger 40 and reduces the amount of cooling required from the inner compartment 42, which in turn requires a smaller portion of the heat of the generator 12 to be used in distilling off that portion of the refrigerant vapor that is condensed in the condenser 38 and flows as liquid refrigerant to the inner compartment 42, of the evaporation

heat exchanger 40, and is subsequently evaporated so as to be absorbed in the absorber 92. Thus if one is seeking high coefficient of performance instead of simplicity this modified system using two sections for the evaporator at two temperatures and pressures would be preferred.

The refrigeration apparatus embodying the teachings of this invention has several advantages. For instance this apparatus has the capability of using nontoxic and nonflammable fluorocarbon refrigerants efficiently so that the apparatus can be safely placed in the living area of a structure. Also the pressure and temperature within the generator of this refrigeration apparatus is minimized. Further the volume of rich solution to be pumped back to the generator is minimized, thus reducing pumping requirements. In addition, the overall efficiency of this absorption-type refrigeration system utilizing nonpolar working substances is maintained at a reasonable overall efficiency or C.O.P. Another advantage of this absorption-type refrigeration apparatus is that it can operate efficiently with nonpolar refrigerants from which several can be chosen with vapor pressure hundreds of times greater than the vapor pressure of water at similar temperature and thus so that the evaporator can be located at a convenient place that may be considerable distance from the rest of the apparatus. A further advantage of this apparatus is that it can use working substances that will not freeze or solidify at even freezing temperatures. A further advantage of this absorption-type refrigeration apparatus is that it can operate with sufficient temperature spread between evaporator on the one hand and absorber and condenser on the other hand that all the waste heat can be dissipated to the ambient air without the use of a water-cooling tower. Another advantage of this absorption-type refrigeration apparatus is that it will permit the same cooling air to first be used to cool the ambient cooled absorbers and then cool the condenser which is operating at a higher temperature than the ambient cooled absorbers while at the same time maintaining a good coefficient of performance for the absorption-type refrigeration apparatus. A further advantage of this absorption-type refrigeration system is that the condenser can be operated at a temperature above that of the first stage ambient cooled absorber receiving refrigerant vapor from the evaporator, while at the same time maintaining the temperature of the evaporator heat exchanger, which is evaporatively cooled, below the temperature of the first stage ambient cooled absorber. Another advantage is to permit, in an absorption-type refrigeration system, a greater practical operating temperature difference between the condenser and the evaporator.

I claim as my invention:

1. A refrigeration system comprising the following connected to form a closed system; generator means for vaporizing refrigerant; a condenser for condensing refrigerant received from said generator means; evaporator means for evaporating refrigerant and providing a cooling effect; an absorber for receiving absorbent material from said generator means and for absorbing refrigerant vapor received from said evaporator means; a preheat exchanger thermally disposed to absorb heat given off by the action within said absorber; an evaporation heat exchanger having a first compartment and a second compartment disposed in heat transfer relationship with the first compartment, said evaporation heat exchanger being operatively associated with said absorber and with said condenser so that a solution of refrigerant and absorbent material passes from said absorber into the first compartment of said evaporation heat exchanger and so that condensed refrigerant passes from said condenser into the second compartment of said evaporation heat exchanger, said evaporation heat exchanger also being operatively associated with said evaporator means so that a portion of the refrigerant evaporated within said evaporator means passes into the first compartment of said evaporation heat exchanger and is absorbed by the absorbent material disposed therein; another absorber operatively associated with the second compartment of said evaporation heat exchanger so as to draw refrigerant

vapor therefrom and thus reduce the pressure with such second compartment and thereby effect evaporation of at least a portion of the condensed refrigerant within such second compartment and thus reduce the temperature of the solution of refrigerant and absorbent material disposed within the first compartment of said evaporation heat exchanger and thus increase the saturation concentration of refrigerant in the solution of refrigerant and absorbent material disposed within the first compartment of said evaporation heat exchanger; first delivery means for delivering a portion of the solution of refrigerant and absorbent material of increased refrigerant concentration from the first compartment of said evaporation heat exchanger and into said another absorber at a pressure that is higher than the pressure within the first compartment of said evaporation heat exchanger to thereby further increase within said another absorber the saturation concentration of refrigerant in solution of refrigerant and absorbent material and for delivering another portion of the solution of refrigerant and absorbent material of increased refrigeration concentration from the first compartment of said evaporation heat exchanger through said preheat exchanger and into said generator means; and second delivery means for delivering at least a portion of the solution of refrigerant and absorbent material that is further increased in concentration of refrigerant from said another absorber and into said generator means.

2. The refrigeration system in accordance with claim 1 in which said first delivery means and said second delivery means each includes a pump.

3. The refrigeration system in accordance with claim 1 in which a heat exchanger is interposed in the system so as to effect heat exchange between at least a portion of the condensed refrigerant passing from said condenser into the second compartment of said evaporation heat exchanger and at least a portion of the solution of refrigerant and absorbent material of increased refrigerant concentration that is delivered by said first delivery means from the first compartment of said evaporation heat exchanger.

4. A refrigeration system comprising the following connected to form a closed system; generator means, including a rectifier section, for vaporizing refrigerant; a condenser for condensing refrigerant received from said generator means; evaporator means for evaporating refrigerant and providing a cooling effect; an absorber for receiving absorbent material from said generator means and for absorbing refrigerant vapor received from said evaporator means; a preheat exchanger thermally disposed to absorb heat given off by the action within said absorber; an evaporation heat exchanger having a first compartment and a second compartment disposed in heat transfer relationship with the first compartment, said evaporation heat exchanger being operatively associated with said absorber and with said condenser so that a solution of refrigerant and absorbent material passes from said absorber into the first compartment of said evaporation heat exchanger and so that condensed refrigerant passes from said condenser into the second compartment of said evaporation heat exchanger, said evaporation heat exchanger also being operatively associated with said evaporator means so that a portion of the refrigerant evaporated within said evaporator means passes into the first compartment of said evaporation heat exchanger and is absorbed by the absorbent material disposed therein; another absorber operatively associated with the second compartment of said evaporation heat exchanger so as to draw refrigerant vapor therefrom and thus reduce the pressure within such second compartment and thereby effect evaporation of at least a portion of the condensed refrigerant within such second compartment and thus reduce the temperature of the solution of refrigerant and absorbent material disposed within the first compartment of said evaporation heat exchanger and thus increase the saturation concentration of refrigerant in the solution of refrigerant and absorbent material disposed within the first compartment of said evaporation heat exchanger; first delivery means for delivering a portion of the solution of

refrigerant and absorbent material of increased refrigerant concentration from the first compartment of said evaporation heat exchanger and into said another absorber at a pressure that is higher than the pressure within the first compartment of said evaporation heat exchanger to thereby further increase within said another absorber the saturation concentration of refrigerant in solution of refrigerant and absorbent material and for delivering another portion of the solution of refrigerant and absorbent material of increased refrigerant concentration from the first compartment of said evaporation heat exchanger through said preheat exchanger and into said generator means; and second delivery means for delivering at least a portion of the solution of refrigerant and absorbent material that is further increased in concentration of refrigerant from said another absorber to the rectifier section of said generator means.

5. The refrigeration system in accordance with claim 4 in which said first delivery means and said second delivery means each includes a pump.

6. A refrigeration system comprising the following connected to form a closed system: generator means, including a rectifier section and an analyzer section, for vaporizing refrigerant; a condenser for condensing refrigerant received from said generator means; evaporator means for evaporating refrigerant and providing a cooling effect; a first absorber for receiving absorbent material from said generator means and for absorbing refrigerant vapor received from said evaporator means; an evaporation heat exchanger having a first compartment and a second compartment disposed in heat transfer relationship with the first compartment, said evaporation heat exchanger being operatively associated with said first absorber and with said condenser so that a solution of refrigerant and absorbent material passes from said first absorber into the first compartment of said evaporation heat exchanger and so that condensed refrigerant passes from said condenser into the second compartment of said evaporation heat exchanger, said evaporation heat exchanger also being operatively associated with said evaporator means so that a portion of the refrigerant evaporated within said evaporator means passes into the first compartment of said evaporation heat exchanger and is absorbed by the absorbent material disposed therein; an ambient cooled absorber operatively associated with the second compartment of said evaporation heat exchanger so as to receive refrigerant vapor therefrom and thus reduce the pressure within such second compartment and thereby effect evaporation of at least a portion of the condensed refrigerant within such second compartment and thus reduce the temperature of the solution of refrigerant and absorbent material disposed within the first compartment of said evaporation heat exchanger and thus increase the saturation concentration of the refrigerant in the solution of refrigerant and absorbent material disposed within the first compartment of said evaporation heat exchanger; first delivery means for delivering at least a portion of the solution of refrigerant and absorbent material of increased refrigerant concentration from the first compartment of said evaporation heat exchanger and into said ambient cooled absorber at a pressure that is higher than the pressure within the first compartment of said evaporation heat exchanger to thereby further increase within said ambient cooled absorber the saturation concentration of refrigerant in the solution of refrigerant and absorbent material; second delivery means for delivering at least a portion of the solution of refrigerant and absorbent material that is further increased in concentration of refrigerant from said ambient cooled absorber to the rectifier section of said generator means; a generator fluid heat exchanger; third delivery means for delivering absorbent material from the analyzer section of said generator means to said generator fluid heat exchanger and from said generator fluid heat exchanger and into said first absorber; and fourth delivery means for delivering a solution of refrigerant and absorbent material from the rectifier section of said generator means to said generator fluid heat exchanger and from said generator fluid heat exchanger and into said generator means.

7. The refrigeration system in accordance with claim 6 in which said first delivery means and said second delivery means each includes a pump.

8. A refrigeration system comprising the following connected to form a closed system: generator means, including a rectifier section and an analyzer section, for vaporizing refrigerant; a condenser for condensing refrigerant received from said generator means; evaporator means for evaporating refrigerant and providing a cooling effect; a first absorber for receiving absorbent material from said generator means and for absorbing refrigerant vapor received from said evaporator means; a preheat exchanger thermally disposed to absorb heat given off by the action within said absorber; an evaporation heat exchanger having a first compartment and a second compartment disposed in heat transfer relationship with the first compartment, said evaporation heat exchanger being operatively associated with said first absorber and with said condenser so that a solution of refrigerant and absorbent material passes from said first absorber into the first compartment of said evaporation heat exchanger and so that condensed refrigerant passes from said condenser into the second compartment of said evaporation heat exchanger, said evaporation heat exchanger also being operatively associated with said evaporator means so that a portion of the refrigerant evaporated within said evaporator means passes into the first compartment of said evaporation heat exchanger and is absorbed by the absorbent material disposed therein; an ambient cooled absorber operatively associated with the second compartment of said evaporation heat exchanger so as to draw refrigerant vapor therefrom and thus reduce the pressure within such second compartment and thereby effect evaporation of at least a portion of the condensed refrigerant within such second compartment and thus reduce the temperature of the solution of refrigerant and absorbent material disposed within the first compartment of said evaporation heat exchanger and thus increase the saturation concentration of refrigerant in the solution of refrigerant and absorbent material disposed within the first compartment of said evaporation heat exchanger; first delivery means for delivering a portion of the solution of refrigerant and absorbent material of increased refrigerant concentration from the first compartment of said evaporation heat exchanger and into said ambient cooled absorber at a pressure that is higher than the pressure within the first compartment of said evaporation heat exchanger to thereby further increase within said ambient cooled absorber the saturation concentration of refrigerant in solution of refrigerant and absorbent material and for delivering another portion of the solution of refrigerant and absorbent material of increased refrigerant concentration from the first compartment of said evaporation heat exchanger through said preheat exchanger and into said generator means; second delivery means for delivering at least a portion of the solution of refrigerant and absorbent material that is further increased in concentration of refrigerant from said ambient cooled absorber to the rectifier section of said generator means; a generator fluid heat exchanger; third delivery means for delivering absorbent material from the analyzer section of said generator means to said generator fluid heat exchanger and from said generator fluid heat exchanger and into said first absorber; and fourth delivery means for delivering a solution of refrigerant and absorbent material from the rectifier section of said generator means to said generator fluid heat exchanger and from said generator fluid heat exchanger and into said generator means.

9. The refrigeration system in accordance with claim 8 in which said first delivery means and said second delivery means each includes a pump.

10. A refrigeration system comprising the following connected to form a closed system: generator means, including a rectifier section and an analyzer section, for vaporizing refrigerant; a condenser for condensing refrigerant received from said generator means; evaporator means for evaporating refrigerant and providing a cooling effect; a first absorber for receiving absorbent material from said generator means and

for absorbing refrigerant vapor received from said evaporator means; an evaporation heat exchanger having a first compartment and a second compartment disposed in heat transfer relationship with the first compartment, said evaporation heat exchanger being operatively associated with said first absorber and with said condenser so that a solution of refrigerant and absorbent material passes from said first absorber into the first compartment of said evaporation heat exchanger and so that condensed refrigerant passes from said condenser into the second compartment of said evaporation heat exchanger, said evaporation heat exchanger also being operatively associated with said evaporator means so that a portion of the refrigerant evaporated within said evaporator means passes into the first compartment of said evaporation heat exchanger and is absorbed by the absorbent material disposed therewithin; a pre-heat exchanger thermally disposed to absorb heat given off by the action within said first absorber to preheat and supply to said generator means solution of refrigerant and absorbent material that originates from said evaporation heat exchanger; another absorber operatively associated with the second compartment of said evaporation heat exchanger so as to receive refrigerant vapor therefrom and thus reduce the pressure within such second compartment and thereby effect evaporation of at least a portion of the condensed refrigerant within such second compartment and thus reduce the temperature of the solution of refrigerant and absorbent material disposed within the first compartment of said evaporation heat exchanger and thus increase the saturation concentration of the refrigerant in the solution of refrigerant and absorbent material disposed within the first compartment of said evaporation heat exchanger; first delivery means for delivering at least a portion of the solution of refrigerant and absorbent material of increased refrigerant concentration from the first compartment of said evaporation heat exchanger and into said another absorber at a pressure that is higher than the pressure within the first compartment of said evaporation heat exchanger to thereby further increase within said another absorber the saturation concentration of refrigerant in the solution of refrigerant and absorbent material; second delivery means for delivering at least a portion of the solution of refrigerant and absorbent material that is further increased in concentration of refrigerant from said another absorber to the rectifier section of said generator means; an inductor having a secondary inlet connected to receive refrigerant vapor from said evaporator means, a primary nozzle for receiving absorbent material, and a discharge connected to discharge absorbent material into said first absorber; a generator fluid heat exchanger; third delivery means for delivering absorbent material from the analyzer section of said generator means to said generator fluid heat exchanger and from said generator fluid heat exchanger to the primary nozzle of said inductor; and fourth delivery means for delivering a solution of refrigerant and absorbent material from the rectifier section of said generator means to said generator fluid heat exchanger

and from said generator fluid heat exchanger and into said generator means.

11. A refrigeration system comprising the following connected to form a closed system: generator means, including a rectifier section for vaporizing refrigerant; a condenser for condensing refrigerant received from said generator means, the vapor pressure within said condenser being at substantially the same value as the vapor pressure within said generator means; evaporator means for evaporating refrigerant and providing a cooling effect; an absorber for receiving absorbent material from said generator means and for absorbing refrigerant vapor received from said evaporator means, at least a portion of said absorber being ambient cooled; an evaporation heat exchanger having a first compartment and a second compartment disposed in heat transfer relationship with the first compartment, said evaporation heat exchanger being operatively associated with said absorber and with said condenser so that a solution of refrigerant and absorbent material passes from said absorber into the first compartment of said evaporation heat exchanger and so that condensed refrigerant passes from said condenser into the second compartment of said evaporation heat exchanger, said evaporation heat exchanger also being operatively associated with said evaporator means so that a portion of the refrigerant evaporated within said evaporator means passes into the first compartment of said evaporation heat exchanger and is absorbed by the absorbent material disposed therewithin; another ambient cooled absorber operatively associated with the second compartment of said evaporation heat exchanger so as to receive refrigerant vapor therefrom and thus reduce the pressure within such second compartment and thereby effect evaporation of at least a portion of the condensed refrigerant within such second compartment and thus reduce the temperature of the solution of refrigerant and absorbent material disposed within the first compartment of said evaporation heat exchanger and thus increase the saturation concentration of the refrigerant in the solution of refrigerant and absorbent material disposed within the first compartment of said evaporation heat exchanger; first delivery means, including a pump, for delivering at least a portion of the solution of refrigerant and absorbent material of increased refrigerant concentration from the first compartment of said evaporation heat exchanger and into said another ambient cooled absorber at a pressure that is higher than the pressure within the first compartment of said evaporation heat exchanger to thereby further increase within said another ambient cooled absorber the saturation concentration of refrigerant in the solution of refrigerant and absorbent material; and second delivery means, including a pump, for delivering at least a portion of the solution of refrigerant and absorbent material that is further increased in concentration of refrigerant from said another ambient cooled absorber to the rectifier section of said generator means.

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